Interface Characterization via Spin Dependent Charge Pumping

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Electrically detected magnetic resonance (EDMR) has been very useful in the study of point defects in semiconductor/insulator heterojunctions. Nearly all of these EDMR interface studies have utilized spin dependent recombination (SDR). Although SDR EDMR is quite sensitive (>10^7 times the sensitivity of EPR). It utilizes a recombination current, so it is only highly sensitive to deep level defects. We show that a new EDMR technique, spin dependent charge pumping (SDCP) [1], overcomes this limitation, allowing EDMR measurements of defects with levels in most of the band gap. SDCP is also significantly more sensitive than SDR based interface methods. In SDCP, a trapezoidal waveform is applied to the gate which cycles the Fermi level from near the conduction to valence band edges. Interface traps are filled, then emptied which creates a current that allows measurement of defects throughout most of the band gap. Like SDR EDMR, we find the sensitivity of SDCP is very nearly field and frequency independent, allowing for a wide range of resonance frequency and field SDCP measurements from 5600 Gauss to 35 Gauss. In addition, we find that there is a strong SDCP response near zero magnetic field. We believe this response involves physics similar to the low field magnetoresistance observed in organic semiconductors. SDCP at low resonance field and frequencies allows for: (1) partial separation of spin-orbit coupling and hyperfine effects on magnetic resonance spectra, (2) observation of otherwise forbidden half-field effects [2] which make EDMR, at least in principle, quantitative, and (3) observation of Breit-Rabi shifts [3] in superhyperfine measurements. We present results on 4H-SiC MOSFETs, but the approach utilized should be widely applicable to other heterointerfaces such as Si/SiO_2, Si/High-K, and SiGe/insulator systems. Although the abstract length is too short to discuss all results, we illustrate a representative ultra-low resonance frequency SDCP spectrum in Fig.1. Fig. 1(a) illustrates the Breit-Rabi shift of the 10.4 Gauss doublet, a hydrogen complexed E' center spectrum. Fig. 1(b) illustrates the half-field resonance response due to "forbidden" transitions created by magnetic dipole-dipole moment interaction between defects. Its intensity, in principle, allows a precise quantitative measurement of the defect density via EDMR [4]. The strong response near zero magnetic field can provide some hyperfine information and EDMR-like detection in fully processed devices without the expense and complexity of a resonance spectrometer. This work supported by the U. S. Army Research Laboratory.

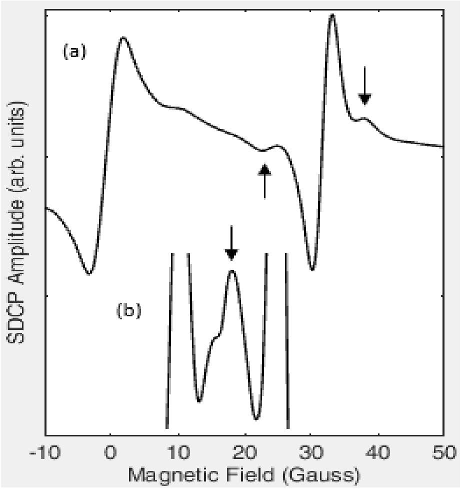

Figure 1. (a) 85 MHz SDCP spectra of the asymmetric hyperfine peaks (indicated by arrows) and (b) a second derivative illustration of the half-field response increased by 40x (indicated by arrow).

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